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CAX System Architecture and Services

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Abstract

The architecture of CAX Systems can be seen from three different perspectives: the Logical or Functional Perspective, the CAX System Topology and the System Physical Architecture. Each of these different views with its different layouts will be described in the paper. A comparison of different CAX Architectural Options based on the functional architecture and assessment criteria such as User Satisfaction, Implementation/Operation & Maintenance Cost, Security, Technological Trends and Flexibility follows.

The trend in the development of complex software systems goes to the use of so-called services. This approach and services to be used in building CAX systems are described.

1 Introduction

The CAX Architecture is addressed here from three perspectives:

The **Logical or Functional Perspective**. This view focuses on the logical or functional interrelationship of the CAX System Components and constitutes the **Functional Architecture of the CAX System**. The Functional CAX Architecture described in 1 is derived from military operational needs and it is not constrained by any system topology or other CAX System Implementation considerations.

The **CAX System Topology**. This view defines and evaluates available options for providing the CAX functionality. As the first step in this process, six options are identified, each with a different degree of integration of CAX with CCIS and with a different degree of distribution of the CAX functionality itself. The second step is then to compare the CAX Architectural Options and come up with advantages and disadvantages of each of them. This analysis, provided in Section 2, is based on the Functional Architecture as well as on a set of assessment criteria such as User Satisfaction, Implementation/Operation & Maintenance Cost, Security, Technological Trends and Flexibility.

The **CAX System Physical Architecture** describes hardware and software components and their interrelationships for the CAX system. In future CCIS, as in other modern information systems, this physical architecture will not play the role it is playing today. New technologies available to implement functions on distributed systems and global data links will make it possible to concentrate on the functional and topological design of the systems. Even changes from one physical architecture to another regarding the distribution of functions in a network will be no major problem and will give the opportunity to decide on topological architectures as described in chapter 2 in accordance with the exercise requirements. Chapter 3 introduces the discussion on possible implementation options for the different topological CAX architectures.

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2 CAX Functional Architecture

The (military) operational needs dictate that CAX and Decision Support Tools (DST) are integrated with the Command and Control Information System (CCIS). The Users should be able to use their CAX System from their location, through their operational CCIS. CAX and DST are considered as essential tools not only for training but also for Crisis Management. Although existing Simulation Models are focusing on training in the classical sense, the simulation technology has now been recognised as a powerful tool for:

(1) Situation Analysis;

(2) Sizing & Composition of Forces;

(3) Expanding the ability to respond to unexpected situations (Crisis Management);

(4) Exercising the operational CCIS for assessing system performance criteria such as functionality, flexibility, availability and reliability.

The full set of the operational needs, as perceived today, expands the traditional scope of a CAX Training System to include the following:

(1) Role Playing;

(2) Problem Solving;

(3) Case Studies (Role Playing);

(4) Analytical Simulation;

(5) War Gaming;

(6) Decision Support (What If).

The Training Subjects are required to cover:

(1) Military Operations;

(2) Rules of Engagement (Military, Political);

(3) Non-Military Missions (Crowd control, Civil population support, Environment protection);

(4) Time and Space Limitations (Planning Systems, Focus on Logistics, Mobility, Deployment, Evacuation);

(5) Crisis Management Functions (Political, Military Strategic, Military Tactical, Military procedural).

The Functional Architecture of a CAX and Decision Support System that could be implemented with existing Simulation Models but flexible enough and expansible to gradually cover all the training subjects listed above, is shown in the following diagram:

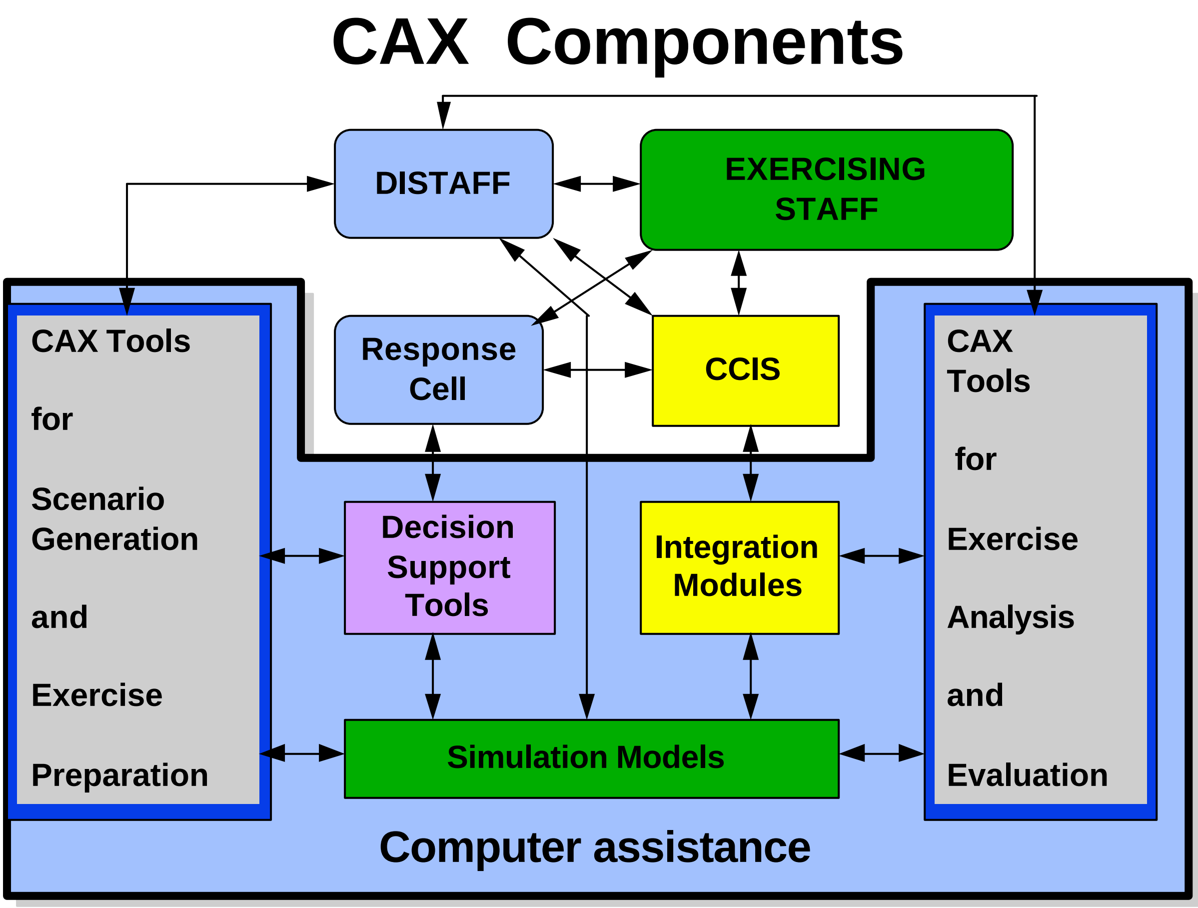

Figure 1: CAX Components

2.1 CAX Components

The Main CAX and DST Components are:

(1) Supporting Tools for Exercise Scenario Generation and for Exercise Preparation (Data Gathering etc.);

(2) Simulation Models for War Gaming;

(3) Integration Modules for:

- Integrating the Simulation Models with the CCIS

- Integrating the Simulation Models with the Supporting Tools

- Integrating the Simulation Models themselves;

(4) Decision Support Tools;

(5) Supporting Tools for Exercise Analysis and Evaluation.

Following is a short description of each component:

The Scenario Generation and Exercise Preparation Tools allow users to develop scenarios for different exercises, presenting those exercised with a variety of different situations. These scenarios can range from low to mid to high intensity. Scenarios can be developed for a specified period of time and can be edited as

necessary. This tool will also allow controllers to produce documentation manuals. The scenario database of pre-selected CAX models should be accessible by the Exercise Controllers, who should have the capability to create, modify, and delete scenario elements. The Exercise Preparation Tools affect the exercise during the preparation phase. This function consists of entering start date data into the system. This will include force strengths, readiness factors, logistical status, and other data related to the friendly and enemy forces participating in the exercise.

The **Simulation Models** are the exercise drivers. They simulate combat operations as well as mobility and logistics. Future models are expected to cover the total spectrum of functions required by the Training Subjects.

The Integration Modules ensure the following interfaces:

(1) The interface between Simulation Models (This component is necessary to integrate different Simulation Models (e.g. Air and Land Models) in one Exercise. This is currently achieved though the High Level Architecture Protocol (HLA)).

(2) The interface between the Simulation Models and the CCIS

(3) The interface between the Simulation Models and the Decision Support Tools

The **Decision Support Tools,** as a CAX component, determine how the CAX capability can be used within the Command and Control Cycle (Maintain Status-Assess Situation- Plan- Decide- Execute) in support of the decision making process.

The **Exercise Analysis and Evaluation Tools** assist in gathering statistics and other information to conduct after-action-reviews at the conclusion of the exercise. A standard set of analytical tools should be available to evaluate the performance of those involved in the exercise.

3 CAX System Topology

3.1 Organizational Architecture Options

In order to support exercises in an automated manner, the military organisation, NATO or national forces, must decide:

(1) to which extent it wants to own, operate and maintain the capabilities that constitute an exercising environment i.e. to which extent it wants to be responsible for exercising environment components.

(2) where the various components of an exercising environment are physically located.

The first bullet above defines the level of integration of the CAX capability in the CCIS. The second bullet defines the level of distribution or concentration.

In this paragraph, various integration and distribution options are shown and their characteristics discussed. Underlying these options are 2 fundamental assumptions:

(1) exercising elements do not require exercise-specific tools because they use their operational CCIS;

(2) exercising headquarters staffs have the capability to exchange data over a digital network.

Six options will now be presented in which the organisational allocation of exercising environment components is varied. Four components are considered relevant for this discussion:

(1) the exercise preparation component is depicted by a diamond shape

(2) the exercise conduct component is depicted by a hexagon shape

(3) the exercise analysis and evaluation component is depicted by square shape

(4) the simulation component is depicted by a dotted ellipse;

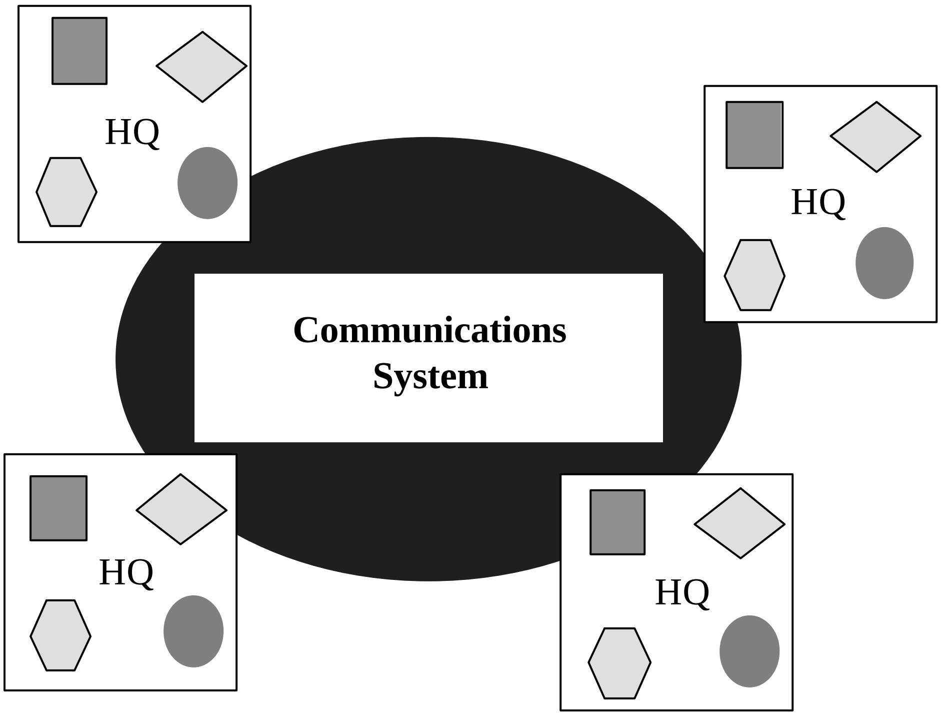

Figure 2: Fully Integrated CAX System Topology (Option 1)

The first option shown here describes a fully integrated architecture. The military organisation takes the responsibility to own, operate and maintain all exercise environment components. Furthermore, distribution is complete as each headquarters is provided with their own capabilities. The components may vary from headquarters to headquarters depending on the exercising requirements of each specific headquarters e.g. the emphasis on certain types of operations or on the level of detail may be different. Using these tools each headquarters can meet its own exercising needs and those of higher command echelons.

The second option shows a fully-integrated architecture. However the organisation has decided to specialise a headquarters in a certain function, in this case the simulation function. Reasons to do this may be that simulation environments require specific expertise, hardware and software to operate and maintain.

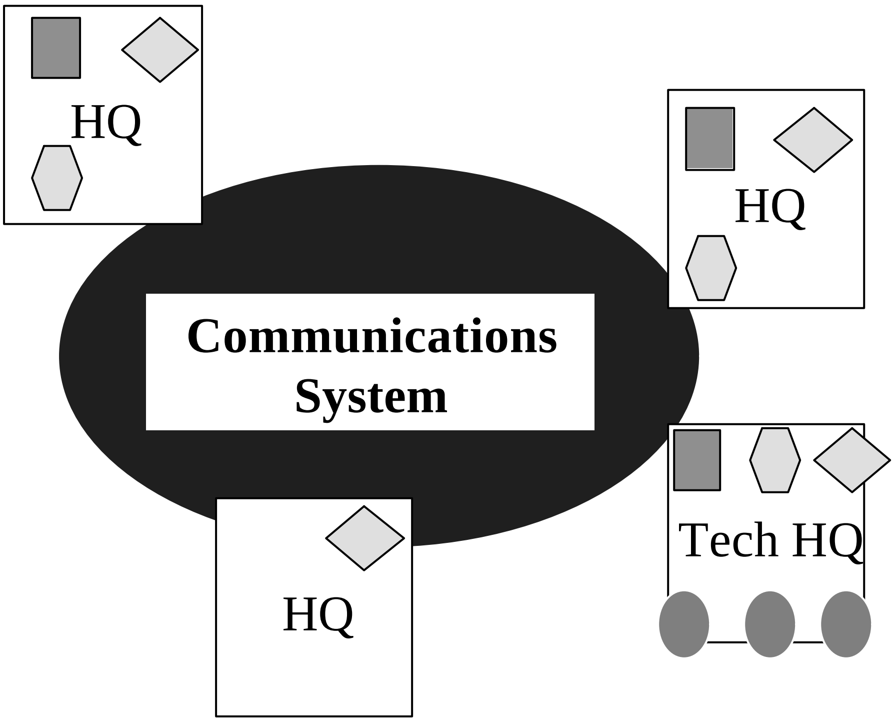

Figure 3: Fully Integrated Architecture with Technical HQ (Option 2)

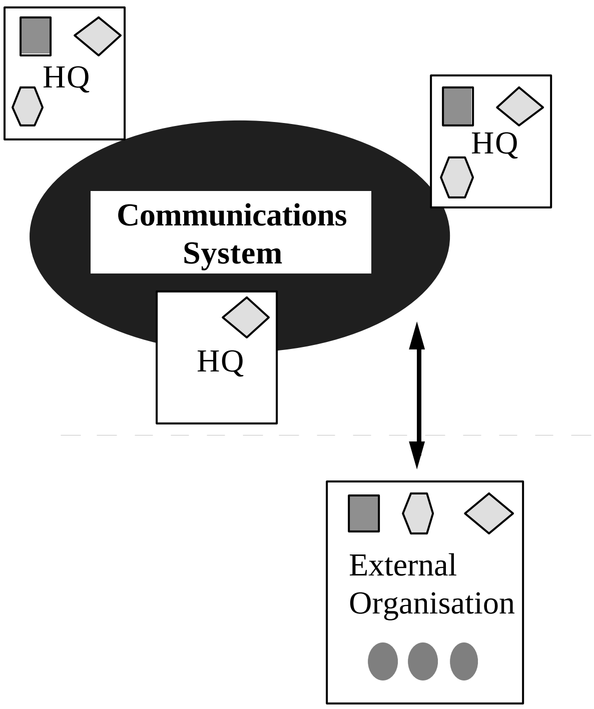

Figure 4: Integrated Architecture with External Organisation (Option 3)

A similar consideration as for option 2 may lead the organisation to leave the responsibility for certain functions with an external service organisation while retaining organisation-specific functions under its own control. This option is illustrated in option 3.

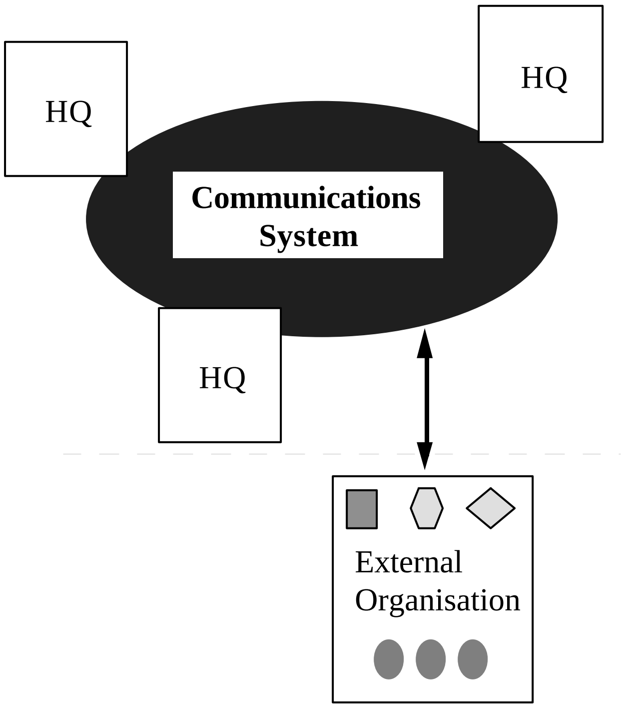

Figure 5: Non-integrated Option (Option 4)

For reasons of lack of specific expertise and capabilities, a non-integrated option can be selected as shown in option 4. The organisation uses tools and capabilities provided by an external service provider. For reasons of reduced management overhead or quality of expertise or unique service capabilities, a single service provider is selected. The exercising components are therefore concentrated within that service provider.

In order to increase the diversity of services, bring market competition factors into play, option 5 can be considered which varies from option 4 in the number and diversity of service providers. Within this option multiple cooperating and complementary service providers may support exercises. The service is therefore distributed.

Option 6 shows a variation on options 2 and 5. Indeed there is a need for exercise service providers to interface with the CCIS. The security implications of doing so are great. In a world of growing internetting and increasing anonymity of network users, military organisations may fear such an openness and security costs may become prohibitive. Therefore it may be interesting to integrate some functions in the organisation and specialise a headquarters in providing the buffer between the CCIS and the external service providers.

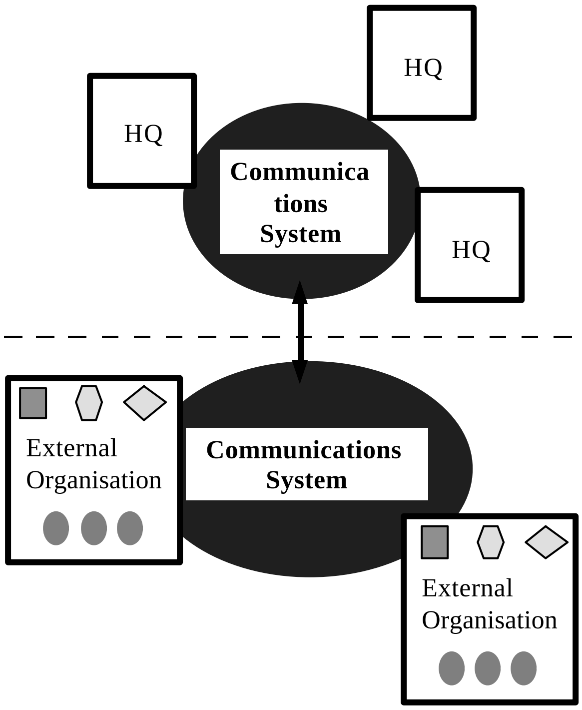

Figure 6: Distributed System with External Service Providers (Option 5)

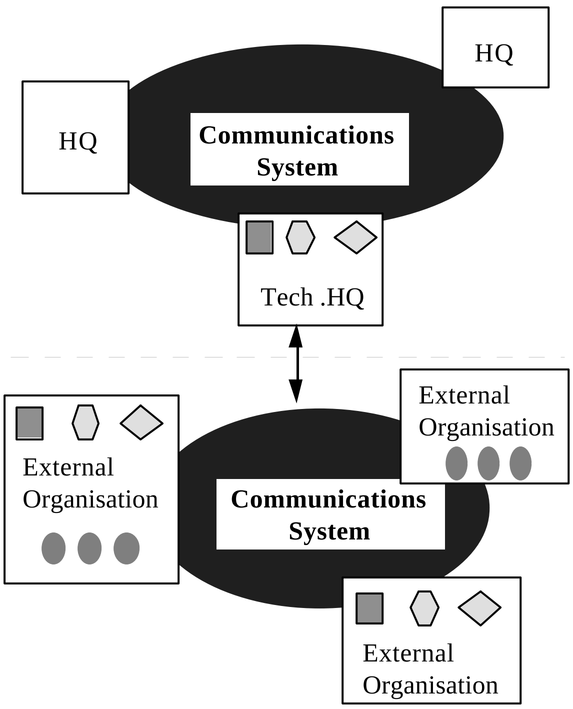

Figure 7: Distributed System with External Providers and Technical HQ (Option 6)

Obviously the permutations shown here are not exhaustive, however they are representative of potential future architectures and highlight the factors that are essential in generating and evaluating architectural options for an organisation, which wants to have the capability to exercise.

3.2 Assessment of the Organizational Architecture Options

The options described in the previous sub-section (3.1) were assessed on the basis of a set of criteria in order to derive some conclusions with respect to advantages and disadvantages of each option in comparison with the other options.

The criteria used for the assessment are the following:

(1) Satisfaction of all parties involved.

The parties involved are the Exercising Staff (trainees), the Control Staff (DISTAFF), the System responsible for the Operation and Maintenance and the System or Service Suppliers (Providers). This criterion covers the degree of support the involved parties can have in performing their role within the CAX activities. The criterion is sub-divided to cover:

(a) The parties involved in the exercise preparation;

(b) The parties involved in the Exercise Control;

(c) The Trainees;

(d) The parties involved in post-Exercise Analysis and

(e) The System "owner".

(2) Implementation Cost.

This criterion is self-explanatory.

(3) Cost and Effort for Operation and maintenance.

This is also self-explanatory.

(4) Security.

This is considered to be a critical factor for the adoption or rejection of an option for implementation.

(5) Openness to Suppliers.

The objective here is to be open to as many suppliers as possible in order to make maximum use the products available in the market.

(6) Operational Control of the CAX system.

The users prefer to have the maximum possible control over the systems they use. This is, to some extends an operational need, but also is related to the availability of the system to the user.

(7) Technological Trends.

This criterion examines to what extend the option follows the technological trends, as perceived today.

(8) Flexibility.

This criterion covers the degree to which the option facilitates the introduction of new applications, covering existing or new requirements, as the technology will offer more and more opportunities for this direction.

(9) Redundancy/Reliability.

This criterion covers all issues related to the availability of the system for the user, when needed, without interruption.

The table shown in the next page summarises the results of the assessment made by the expert group of the six CAX distribution options described in section 2.

The following conventions are used:

(+) indicates an advantage of the specific option under the specific criterion;

(++) indicates a strong advantage;

(-) indicates a disadvantage or weakness;

(--) indicates a major disadvantage or weakness;

(0) indicates a neutral situation (no advantage or disadvantage).

Table 1: Assessment of Alternative CAX Organisational Distributions (next page)

	Criteria	Integration	full	semi	semi	none	none	semi
		Service	none	none	partial	full; one	full; many	partial; many
1.								
	Preparation	+	++	+	+	+	+	
	Control	+	++	o	o	-	-	
	Trainees	o	o	o	o	o	o	
	Analysis	+	++	+	+	+	+	
	System ”owner”	--	-	o	++	+	+	
	Summary of 1	(o)	(++)	(o)	(+)	(o)	(o)	
2a)	Cost of Implementation	--	-	+	+	++	o	
2b)	Cost & Effort of Ops & Maint.	--	-	-	-	-	-	
3.	Security	+	++	o	-	--	o	
4.	Openness to Suppliers	-	-	o	++	+	+	
5.	Operational Control	+	++	o	-	-	o	
6.	Technological Trends	-	-	o	+	+	+	
7.	Flexibility to diff. Applic./Req ts.	-	-	o	+	++	+	
8.	Redundancy/Reliability	++	+	+	-	--	o	
	Total Summary	(-)	(++)	o	(++)	(+)	(+)	

The following general conclusions are derived from the above Table1:

(1) Option 1 is assessed to be the most expensive solution in both Implementation and Operation & Maintenance costs; This option is neutral in terms of the satisfaction provided to all parties involved, is very strong in redundancy/reliability, strong in terms of security and operational control and weak in terms of openness to suppliers. It is also less flexible and is not following the technological trends. Overall, this option is rated as weak with most of the disadvantages.

(2) Option 2 , compared with the other options, is the best for the satisfaction of all parties involved in CAX (mainly the users but also the system or service providers); It is also very strong in terms of security, redundancy/reliability and operational control. On the other hand, this option is rather expensive, less open to suppliers, not very flexible and not following the technological trends. Overall, this option is rated as very strong, especially in addressing the security problem as the most critical issue related to the CAX implementation.

(3) Option 3 is neutral with no major advantages or disadvantages.

(4) Option 4 provides a major advantage to the system Owner, is very open to Suppliers and also follows the Technological Trends and provides a high degree of flexibility for future applications. It is weak in redundancy/reliability.

(5) Option 5 involves the lowest Implementation Cost and provides the maximum Flexibility. Major weaknesses are in Security and Redundancy/Reliability.

(6) Option 6 , as a combination of Options 2 and 5, improves Security and Redundancy/Reliability, compared with Option 5 but involves higher Implementation Cost and lower degree of Flexibility.

4 CAX Physical Architecture

As described in the introduction of chapter 5, the CAX System Physical Architecture depends highly on available hardware and software solutions that will also be used for CCIS where the CAX system is to be integrated.

The assumptions for the topological architecture are that users of exercise environments will use their day-to-day working environment and that the HQs have the capability to exchange information amongst each other and with external organisations supplying CAX functions. These assumptions could be amended by the assumption that in every HQ and at the external organisations computational resources will be available to implement specific CAX functions.

Distributed Object systems and services will provide services that are beyond today's available client-server architectures. The server is now a function that could be also distributed on different computers on the network. This technology will allow solutions like the one described in ANNEX VIII but let it open to distribute the CAX system with its different functional parts on the network.

The different options for the topological architecture will not fix specific physical architectures because of the described assumptions.

5 SERVICES

The development of information technologies shows a general trend to move the system developer, integrator and end-user away from basic technologies to higher aggregated technologies, tools, and services.

The development of software is a good example for this change of view. Software development started with machine coding, came then to assembler programming, programming languages like FORTRAN and

COBOL, high order languages like ADA and C, development tools and environments. Now the object-oriented technology is an emerging paradigm for software development, which includes already dynamic distributed objects and services.

CAX designers/implementers will draw from a large stock of higher aggregated services offering a variety of products serving specified groups of basic tasks. These services will have been built on more basic technologies by others and will be commercial and governmental available. An example for such services is Geographic Information Systems (GIS).

The "art" of building CAX systems and CCIS systems will be to integrate these services into a system which fulfils the requirements. The requirements depend on training objectives that are derived from tasks (war tasks, crisis management, humanitarian aids).

A consequence of these developments is that basic technologies will play a decreasing role for the system designer/integrator; they may even not have to be known in detail.

Services available or to come are of increasing importance as building blocks for functionality and technical architecture of CAX systems and CCIS as opposed to the basic technologies.

6 References

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CAX System Architecture and Services

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NATO C3 Agency

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Topics

- Three Perspectives for System Architecture
  - Functional Perspective
  - System Topology
  - Physical Architecture
- Services

Notes for Slide 2

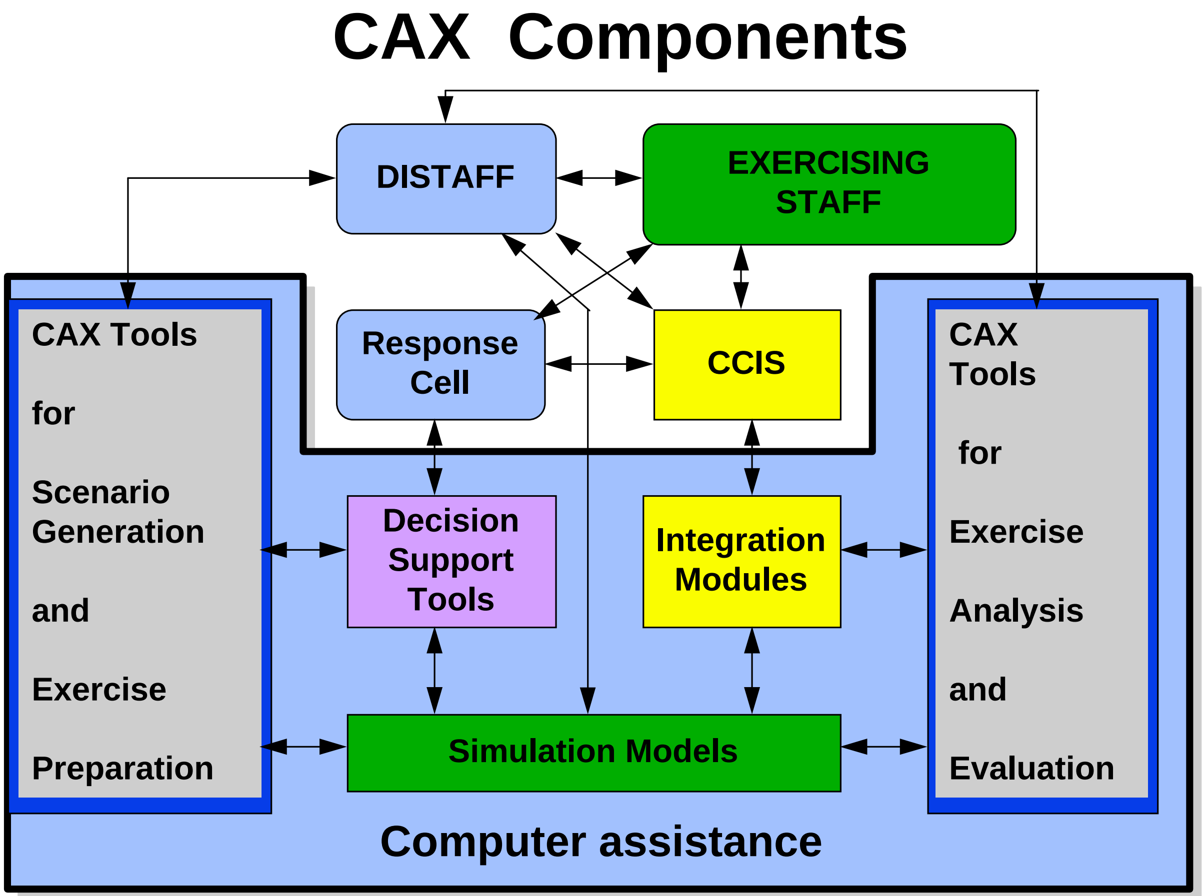
The Logical or Functional Perspective**. This view focuses on the logical or functional interrelationship of the CAX System Components and constitutes the** Functional Architecture of the CAX System**. The Functional CAX Architecture described in 1 is derived from military operational needs and it is not constrained by any system topology or other CAX System Implementation considerations.**

The CAX System Topology**. This view defines and evaluates available options for providing the CAX functionality. As the first step in this process, six options are identified, each with a different degree of integration of CAX with CCIS and with a different degree of distribution of the CAX functionality itself. The second step is then to compare the CAX Architectural Options and come up with advantages and disadvantages of each of them. This analysis, provided in Section 2, is based on the Functional Architecture as well as on a set of assessment criteria such as User Satisfaction, Implementation/Operation & Maintenance Cost, Security, Technological Trends and Flexibility.**

Notes for Slide 2 (Continued)

The **CAX System Physical Architecture** describes hardware and software components and their interrelationships for the CAX system. In future CCIS, as in other modern information systems, this physical architecture will not play the role it is playing today. New technologies available to implement functions on distributed systems and global data links will make it possible to concentrate on the functional and topological design of the systems. Even changes from one physical architecture to another regarding the distribution of functions in a network will be no major problem and will give the opportunity to decide on topological architectures as described in chapter 2 in accordance with the exercise requirements. Chapter 3 introduces the discussion on possible implementation options for the different topological CAX architectures.

Functional Architecture



CAX System Topology – Organizational Architecture Options

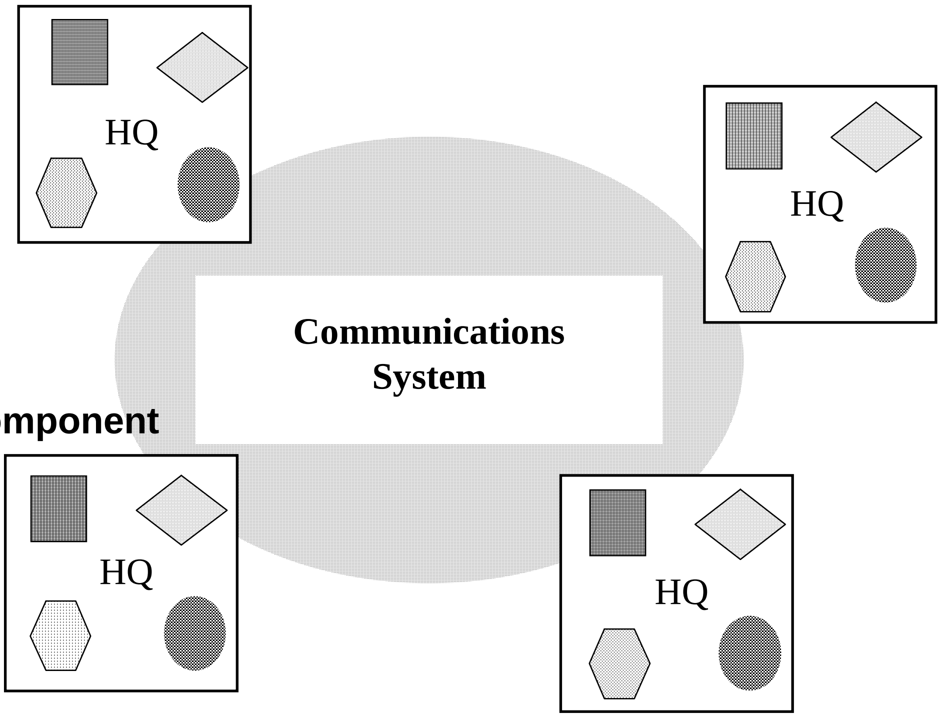
- **Who owns, operates and maintains the capabilities that constitute an exercising environment?**
- **Where are the various components of an exercising environment physically located?**

Exercising Environment Components

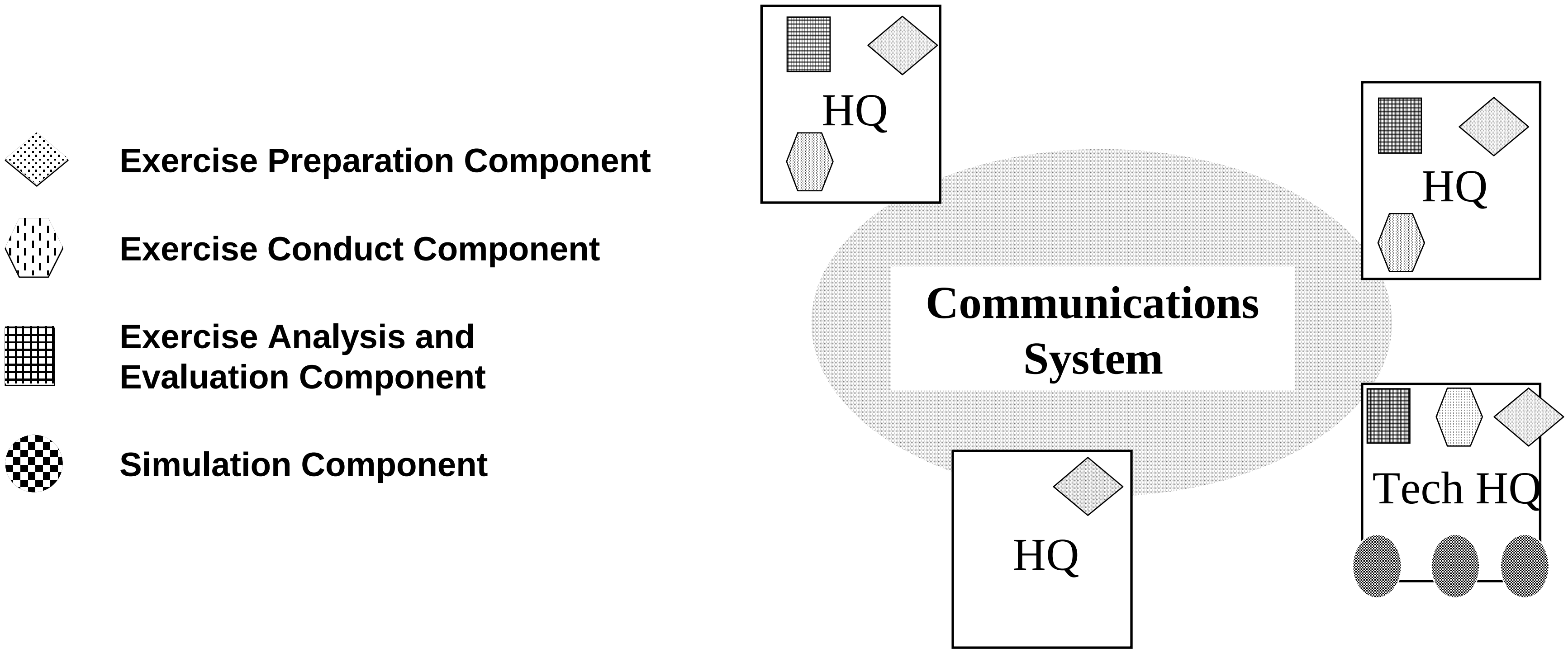
- Exercise Preparation Component
- Exercise Conduct Component
- Exercise Analysis and Evaluation Component
- Simulation Component

Fully Integrated CAX System Topology

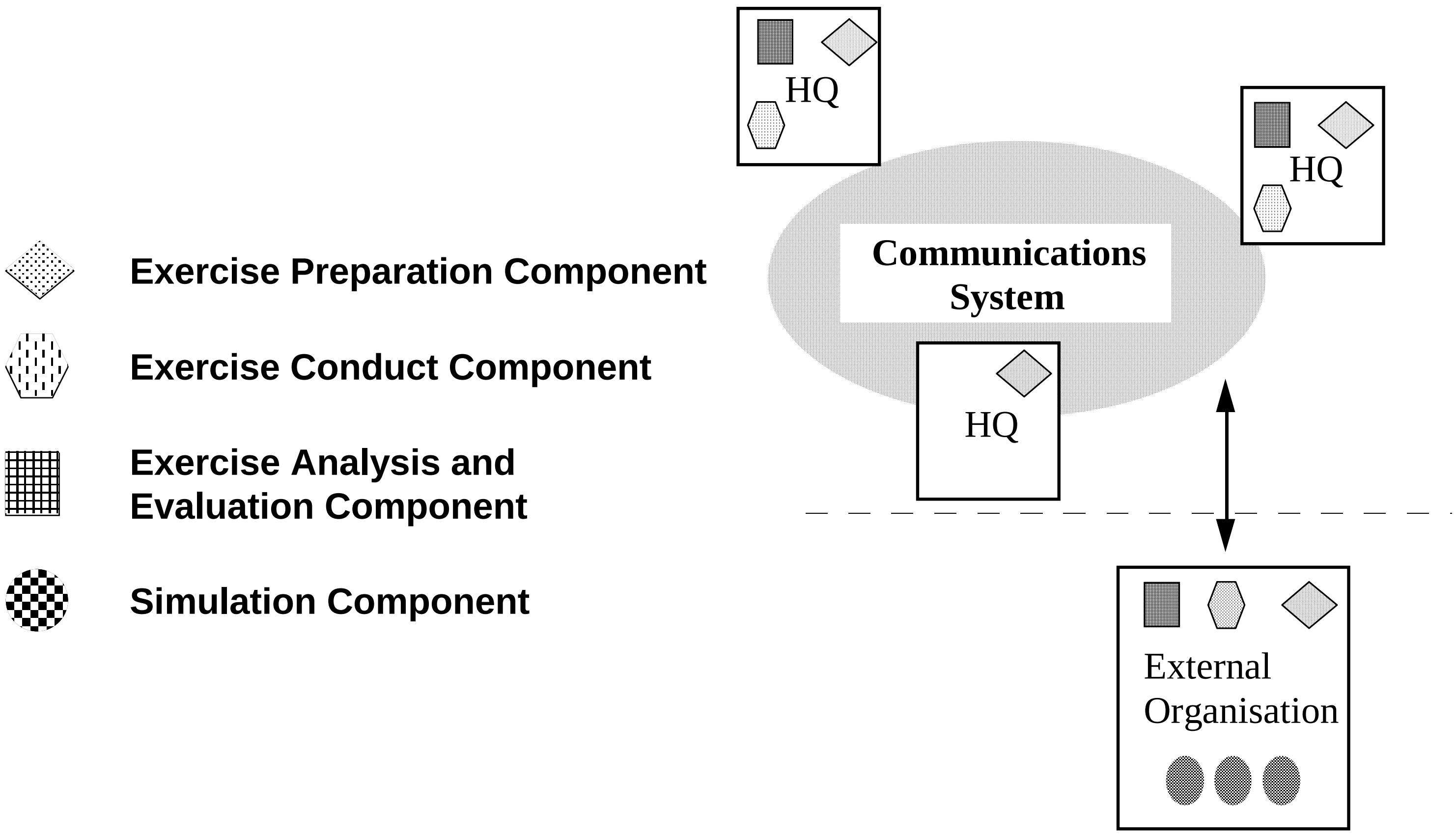
- Exercise Preparation Component
- Exercise Conduct Component
- Exercise Analysis and Evaluation Component
- Simulation Component



Fully Integrated Architecture with Technical HQ



Integrated Architecture With External Organisation



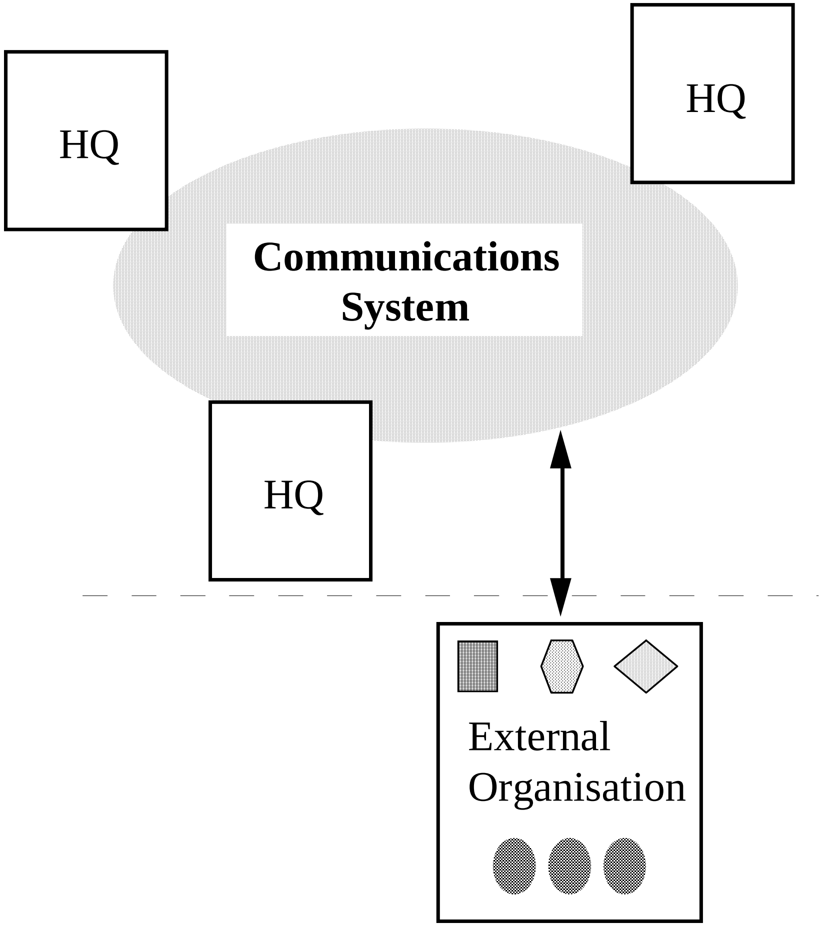
Non-integrated Option

Exercise Preparation Component

Exercise Conduct Component

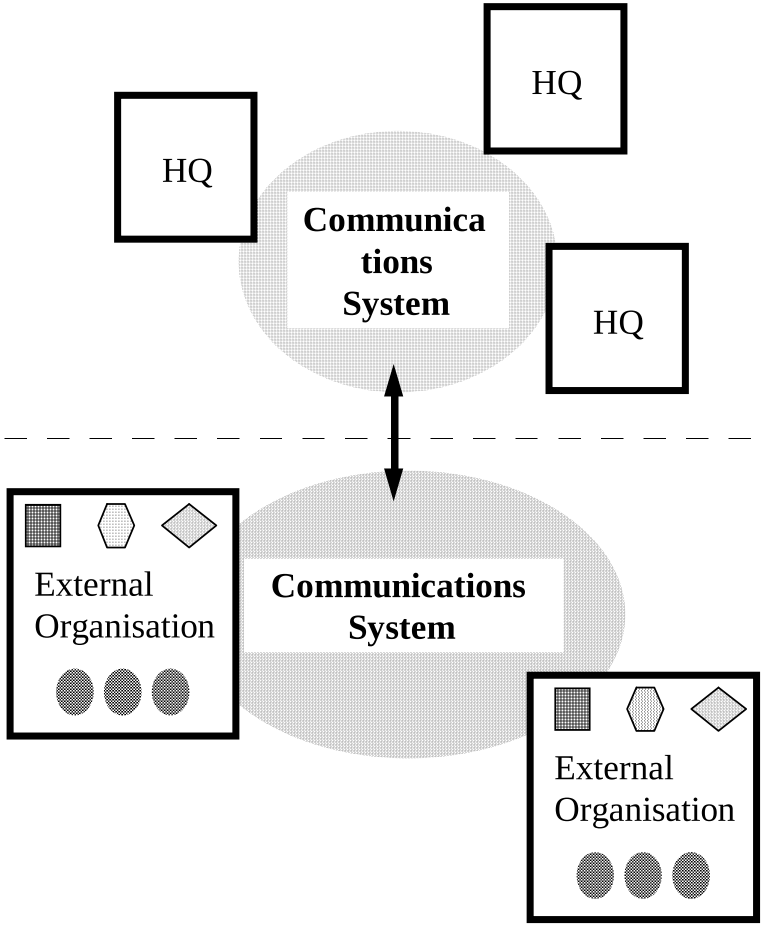
Exercise Analysis and Evaluation Component

Simulation Component



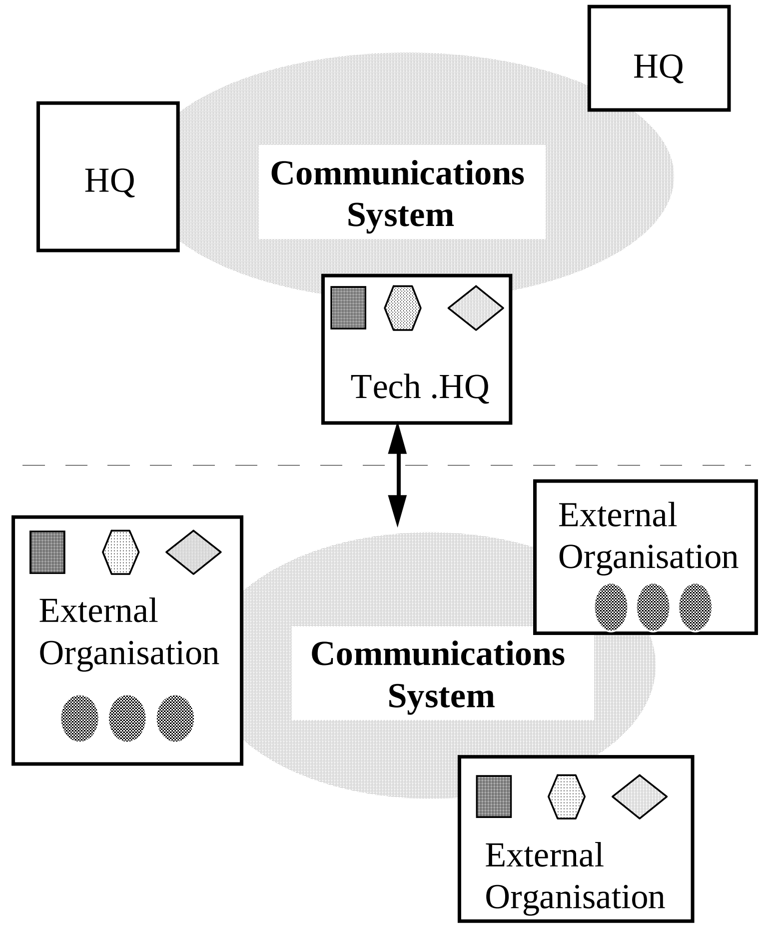
Distributed System
with External Service Providers

- Exercise Preparation Component
- Exercise Conduct Component
- Exercise Analysis and Evaluation Component
- Simulation Component



Distributed System with External Providers and Technical HQ

- Exercise Preparation Component
- Exercise Conduct Component
- Exercise Analysis and Evaluation Component
- Simulation Component



Criteria for an Assessment (I)

- Satisfaction of All Parties Involved in
  - Exercise Preparation
  - In the Exercise Control
  - The Trainees
  - The Parties Involved in Post-exercise Analysis and
  - The System "Owner"
- Implementation Cost
- Cost and Effort for Operation and Maintenance
- Security

Criteria for an Assessment (II)

- Openness to Suppliers
- Operational Control of the CAX system
- Technological Trends
- Flexibility
- Redundancy/Reliability

CAX System Architecture and Services

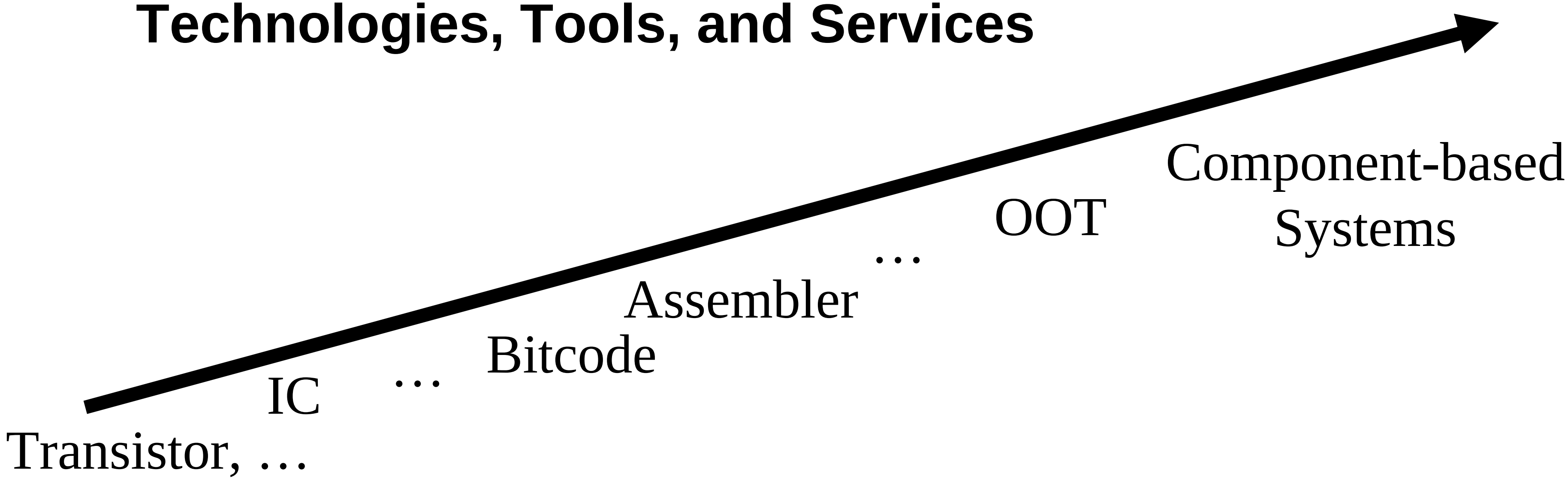
Criteria CCIS Integration	full	full	semi	none	semi	semi
Techn. HQ/External Service	none	techn	ext	full ext	full ext	tech/ext
Preparation	+	++	+	+	+	+
Control	+	++	o	o	-	-
Trainees	o	o	o	o	o	o
Analysis	+	++	+	+	+	+
System ”owner”	--	-	o	++	+	+
Summary of 1	(o)	(++)	(o)	(+)	(o)	(o)
Cost of Implementation	--	-	+	+	++	o
Cost & Effort of Ops & Maint.	--	-	-	-	-	-
Security	+	++	o	-	--	o
Openness to Suppliers	-	-	o	++	+	+
Operational Control	+	++	o	-	-	o
Technological Trends	-	-	o	+	+	+
Flexibility to diff. Applic./Req ts.	-	-	o	+	++	+
Redundancy/Reliability	++	+	+	-	--	o
Total Summary	(-)	(++)	o	(++)	(+)	(+)

Physical Architecture

- **Depends Highly on Available Hardware and Software in CCIS and CAX System**
- **Distributed Services Should Be Used As Basis**

Services

- **General Trend of Moving the System Developer, Integrator and End-user Away From Basic Technologies to Higher Aggregated Technologies, Tools, and Services**



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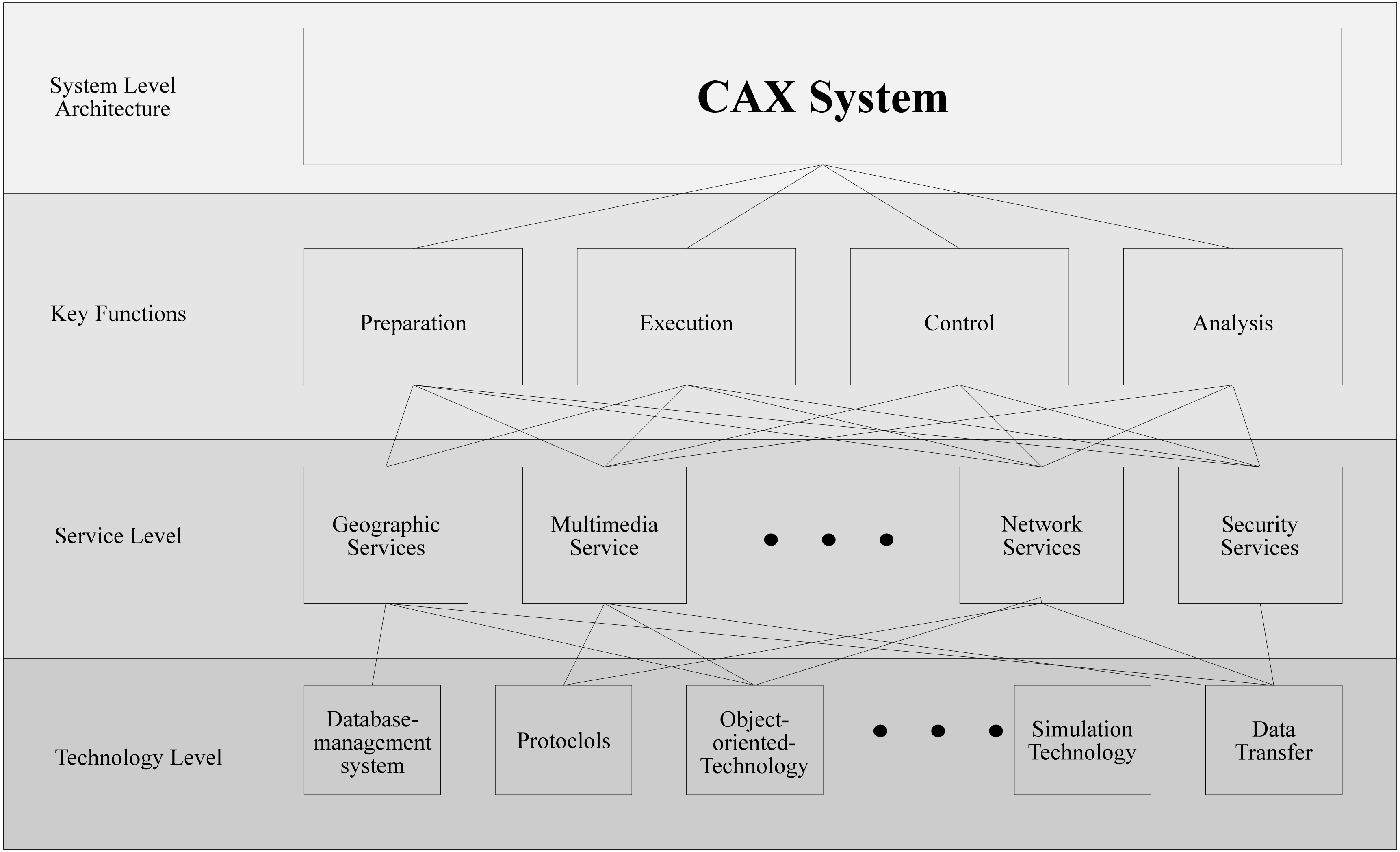
CAX System Architecture and Services



Notes for Slide 17

- Services Instead of Single Technologies will Play a Major Role for Users in the Future

Services (I)

- Messaging and Collaboration
- Communications Systems Planning Services
- Security Services/Packages
- Object-oriented Component Based Technology
- Archiving and Retrieval Technology (A&RT)
- Multimedia Services

Services (II)

- Rapid Prototyping, Simulation Demonstration Environments
- Office Automation Environment
- Workflow Management Systems
- Automated Explanatory Briefings Associate
- Geographical Information Systems